Distortion Analysis of the Historical Maps of Ushu Kaido Road in Akita Domain

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Abstract: In the Edo period, Ushu Kaido Road was a major highway running through Akita Domain from north to south, and has been known as an important transport road connecting Akita Domain and the city of Edo. In this study, the distortion characteristics of the historical maps of Ushu Kaido Road are analyzed, and the information on how the geographic situation of Akita Domain was recognized in the Edo period is extracted. The technique of the Euclidean regression analysis is used to quantitatively extract the distortion characteristics. As a result, the stretch of the map in the east-west direction is confirmed as a remarkable map-distortion characteristic seen in the early Edo period. It is presumed that the geometric arrangement of the counties in the Sengoku period may be the cause of the stretch in the northern part, whereas the geographic separation by mountains and difference in climate conditions between the coastal and inland regions may be that in the southern part.

Keywords: historical map, Akita, Ushu Kaido, map distortion, Euclidean regression

1. Introduction

In the beginning of the Edo period (1603-1868), Akita Domain (Akita Han) was established at the northwestern part of the current Tohoku district, Japan, by the first feudal load Yoshinobu SATAKE [1]. *Ushū Kaidō* Road was a major highway running through Akita Domain from north to south, and has been known as an important transport road connecting the Dewa province (western part of the current Tohoku district, including Akita Domain) and the city of Edo, the capital of Japan at the time [1], [2], [3], [4], [5]. Today, there remain several historical maps describing the state of Akita Domain including that of *Ushū Kaidō* Road in the Edo period.

It is well known that geometric distortion is often seen in historical maps. According to Ref. [6], the above distortion can be interpreted as the reflection of the cognitive structure of the area displayed in a given map. In this study, the distortion characteristics of the historical maps of *Ushū Kaidō* Road are quantitatively analyzed, and the information on how the geographic situation of Akita Domain was recognized in the Edo period is extracted. As will be mentioned in Section 2.1, *Ushū Kaidō* Road has a structure spread over a wide area of Akita Domain. Therefore, it is expected that the characteristics of the entire Akita Domain territory can be extracted by analyzing only *Ushū Kaidō* Road with a small amount of calculation.

Ref. [6] proposes a method to quantitatively extract the information on the distortion of a given historical map. The technique of the Euclidean regression analysis is used in it. The above technique is also adopted in this study and applied to three historical maps of Akita Domain including *Ushū Kaidō* Road, which cover all of the early, mid and late Edo periods. As a result of the analysis, the stretch of the map in the east-west direction is confirmed as a remarkable map-distortion characteristic seen in the early Edo period. It is presumed that the geometric arrangement of the counties controlled by respective different feudal lords may be the cause of the stretch in the northern part, whereas the geographic separation by mountains and difference in climate conditions between the coastal and inland regions may be that in the southern part.

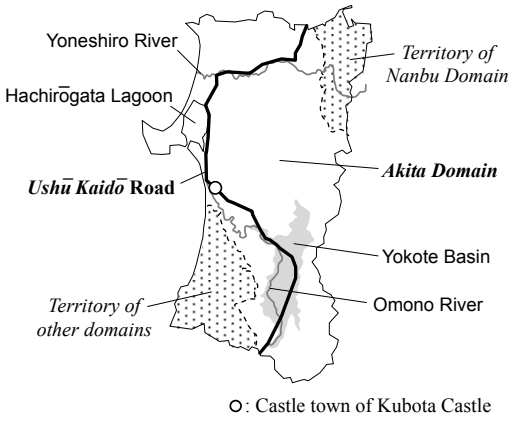
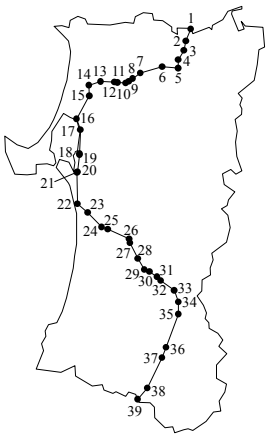


Fig. 1 *Ushū Kaidō* Road in Akita Domain.

2. Historical Maps of *Ushū Kaidō* Road

2.1 Overview of *Ushū Kaidō* Road

Figure 1 shows the geographic information on *Ushū Kaidō* Road in the area of Akita Domain. In the region just north of the castle town of Kubota Castle (i.e., capital of Akita Domain [1]), the Road goes up north along the eastern edge of Hachirōgata Lagoon. In the northernmost region, the Road runs in the east-west direction along Yoneshiro River. As for the region south of the castle town, on the other hand, the



1. Yatate Pass
2. Nagabashiri Village
3. Shirasawa Village
4. Shakanai Village
5. Ōdate Town
6. Kawaguchi Village
7. Tsuzureko Village
8. Bōzawa Village
9. Maeyama Village
10. Imaizumi Village
11. Kotsunagi Village
12. Niageba Village
13. Tobune Village
14. Tsurugata Village
15. Hiyama Village
16. Moritake Village
17. Kado Village
18. Hitoichi Village
19. Ōkawa Village
20. Abukawa Village
21. Ōkubo Village
22. Minato Village
23. Kubota Castle
24. Toyoshima Village
25. Wada Village
26. Sakai Village
27. Yodokawa Village
28. Kariwano Village
29. Kitanaraoka Village
30. Jingūji Village
31. Hanadate Village
32. Ōmagari Village
33. Rokugō Village
34. Kanezawa Village
35. Yokote Town
36. Iwasaki Village
37. Yuzawa Town
38. Shimo-Innai Village
39. Ogachi Pass

Fig. 2 Post towns in *Ushu Kaidō* Road used in distortion analysis (including two mountain passes (Nos. 1 and 39)).

(a) (b) (c)

Fig. 3 Historical maps of Akita Domain (*Ushu Kaidō* Road: added as black poly-lines, dot: castle town of Kubota Castle): (a) *Dewa Rokugun Yasho Ezu* (1645), (b) *Akita-Ryō Ezu* (1729) and (c) *Akita-Ryō Rokugun Ezu* (1849) (Image data: downloaded from "Akita Prefectural Archives Digital Archive" <https://da.apl.pref.akita.jp/koubun> [7]).

Road runs in the southeast direction along Omono River and enters Yokote Basin. Finally, the Road goes down to the other domain. As mentioned above, *Ushū Kaidō* Road is not a simple straight one but has a two-dimensional structure spread over a wide area of Akita Domain.

Figure 2 shows the post towns in *Ushū Kaidō* Road. The 39 post towns (including two mountain passes located at the boundary of Akita Domain) [2], [3], [4], [5] are used in the distortion analysis.

2.2 Historical Maps of *Ushū Kaidō* Road

The three historical maps of Akita Domain shown in **Fig. 3** are analyzed in this study ((a): created in the early Edo period (17th century), (b): mid Edo period (18th century) and (c): late Edo period (19th century)). The image data used in the analysis are downloaded from the web page of "Akita Prefectural Archives Digital Archive" [7]. In Fig. 3, *Ushū Kaidō* Road is drawn in each map as a black poly-line, which is obtained by connecting the 39 post towns in the Road.

The map shown in Fig. 3 (a) is *Dewa Rokugun Yasho Ezu* (The field-book pictorial map of the six counties in the Dewa province) created in 1645 (early Edo period, 655 cm long and 478 cm wide[*1]) [7]. This map is the rough draft of the official pictorial map submitted to the Tokugawa shogunate [7], [8].

The map shown in Fig. 3 (b) is *Akita-Ryō Ezu* (The pictorial map of the territory of Akita Domain) created in 1729 (mid Edo period, 438 cm long and 282 cm wide[*2]) [7]. This map is the copy of the official pictorial map submitted to the Tokugawa

[*1] This map originally puts east on top, and the map of Fig. 3 (a) is that rotated 90 degrees clockwise to put north on top in accordance with the current conventions in surveying. The values of length and width are those of the rotated map.

[*2] This map originally puts east on top, and the map of Fig. 3 (b) is that rotated 90 degrees clockwise to put north on top. The values of length and width are those of the rotated map.

shogunate [7], [8].

The map shown in Fig. 3 (c) is *Akita-Ryō Rokugun Ezu* (The pictorial map of the six counties in the territory of Akita Domain) created in 1849 (late Edo period, 433 cm long and 262 cm wide[*3]) [7]. This map is the copy of the official pictorial map submitted to the Tokugawa shogunate, as the cases of (b) [7].

According to Ref. [9], the direction of south to north in the maps created in the Edo period was adjusted so as to match the direction of the magnetic needle of a compass. To eliminate the influence of the variation of the geomagnetic condition over time, the above historical maps are rotated in advance of analysis by the magnetic-declination angles in respective periods[*4]. On the other hand, the origin of the coordinate system is located at the center of the castle town of Kubota Castle, i.e., the capital of Akita Domain, in all the maps including the present map used as the reference map.

3. Euclidean Regression Analysis

As already mentioned in Section 1, the Euclidean regression analysis is performed to quantitatively extract the information on the distortion of the historical maps of Fig. 3. The Euclidean regression is one of the two-dimensional regression methods belonging to the group of the Helmert transformation, i.e., the set of similarity transformations [6], [10]. It consists of rotation, translation and scale change, and as a result, the geometric shape of a given two-dimensional figure is maintained after the transformation, while adjusting its size and direction to fit those of the reference shape given by the specified dataset. This makes it possible to directly compare the shape of a given figure (in this study, a historical map) with that of the specified reference figure (the present map).

The Euclidean regression formula, which represents the relationship between the positions of the post towns in the present map and those in the historical map, is given as follows [6]:

$$\begin{bmatrix} x_{\mathrm{P}}(i) \\ y_{\mathrm{P}}(i) \end{bmatrix} = c \begin{bmatrix} \cos\theta & -\sin\theta \\ \sin\theta & \cos\theta \end{bmatrix} \begin{bmatrix} x_{\mathrm{H}}(i) \\ y_{\mathrm{H}}(i) \end{bmatrix} + \begin{bmatrix} x_{\mathrm{T}} \\ y_{\mathrm{T}} \end{bmatrix} + \begin{bmatrix} e_x(i) \\ e_y(i) \end{bmatrix} \quad (1)$$

where $x_{\mathrm{P}}(i)$ and $y_{\mathrm{P}}(i)$ are the coordinates of the ith post town in the present map ($1 \le i \le N$, $N = 39$), $x_{\mathrm{H}}(i)$ and $y_{\mathrm{H}}(i)$ are those in the historical map, c is the parameter for scale change, θ is the parameter for rotation, x_{T} and y_{T} are the parameters for translation, and $e_x(i)$ and $e_y(i)$ are the residuals of the coordinate values, respectively. The vector $[\, x'_{\mathrm{P}}(i) \;\; y'_{\mathrm{P}}(i) \,]^{\mathrm{T}}$ shown below is used as the set of the predicted values of $x_{\mathrm{P}}(i)$ and $y_{\mathrm{P}}(i)$:

$$\begin{bmatrix} x'_{\mathrm{P}}(i) \\ y'_{\mathrm{P}}(i) \end{bmatrix} = \begin{bmatrix} x_{\mathrm{P}}(i) - e_x(i) \\ y_{\mathrm{P}}(i) - e_y(i) \end{bmatrix} \quad (2)$$

The values of the parameters c, θ, x_{T} and y_{T} are determined by the least squares method applied to the dataset of the 39 post towns in *Ushū Kaidō* Road shown in Fig. 2.

According to Ref. [6], the residuals $e_x(i)$ and $e_y(i)$ represent the influence of the "local distortion" around each post town, whereas the parameters c, θ, x_{T} and y_{T} represent that of the "common distortion" in the entire area of a given historical map. Ref. [6] points out that it is difficult to interpret the meanings of the c, x_{T} and y_{T} values because of the indefiniteness of scaling in historical maps. As will be shown later, on the other hand, there is no distinct trend in the θ values extracted from the historical maps of Fig. 3. Therefore, only the characteristics of the local distortion are examined here.

4. Results and Discussion

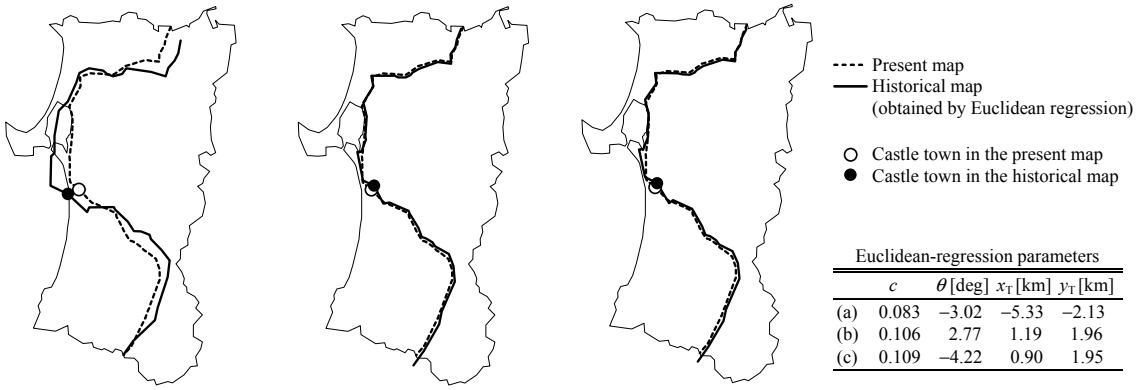
4.1 Results

Figure 4 shows the results of the Euclidean regression analysis for the historical maps of Fig. 3. In Fig. 4, the post towns are plotted at the positions of the points $(x'_{\mathrm{P}}(i),\ y'_{\mathrm{P}}(i))$ $(1 \le i \le N,\ N = 39)$ given by Eq. (2) and connected by black lines. The Euclidean-regression parameter values obtained from each historical map are also shown in the figure. As already mentioned in Section 3, there is no distinct trend in the θ values. As for the arrangement of *Ushū Kaidō* Road in the historical maps, the case of (a) shows a larger local distortion compared with (b) and (c). In particular, the residuals in the transverse, i.e., east-west, direction is remarkable in (a). The coastal (left) part is moved to a more coastal region, whereas the inland (right) part is moved to a more inland region.

To quantitatively summarize the above characteristics, statistics for the post-town positions are used. Specifically, the standard deviation (SD) of each of the x and y components, i.e., the east-west (E-W) and north-south (N-S) components, of the post-town positions is used. **Figure 5** shows the above SDs for the predicted post-town positions in (a), (b) and (c) and those for the actual positions in the present map. It is seen that only the E-W component of (a) gives a remarkably high SD value. This means that only the

[*3] This map originally puts east on top, and the map of Fig. 3 (c) is that rotated 90 degrees clockwise to put north on top. The values of length and width are those of the rotated map.

[*4] The magnetic-declination angles in respective periods are obtained by converting the values shown in Fig. 15 of Ref. [9] (representing the variation of the magnetic declination at Tokyo in the Edo period) to those of Akita Domain.



Euclidean-regression parameters

	c	θ [deg]	x_T [km]	y_T [km]
(a)	0.083	−3.02	−5.33	−2.13
(b)	0.106	2.77	1.19	1.96
(c)	0.109	−4.22	0.90	1.95

Fig. 4 Euclidean regression analysis of *Ushū Kaidō* Road in the historical maps of Akita Domain.

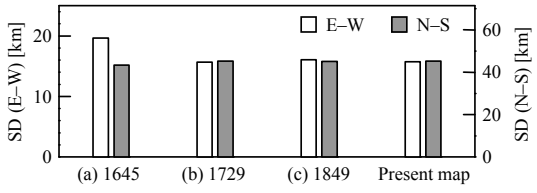


Fig. 5 Standard deviation of the E-W and N-S components of the post-town positions.

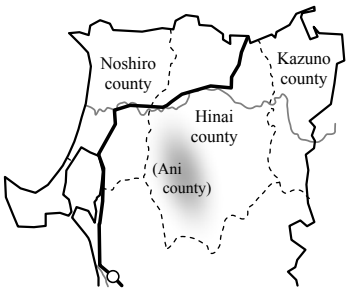
map created in the earlier period shows the stretch in the E-W direction.

4.2 Discussion

As mentioned above, the map of Akita Domain was remarkably stretched in the E-W direction, at least in the early Edo period. In the Sengoku period (1493-1590, late medieval times before the Edo period), the northern part of Akita Domain had been divided into three (or four) counties in the E-W direction as shown in **Fig. 6**: Kazuno, Hinai (or further subdivided into Hinai and Ani) and Noshiro counties [11]. These counties had been controlled by respective different Sengoku feudal lords as shown in the figure [11]. The clans of the feudal lords had hostile relations with each other and frequently fought through the Sengoku period [11], [12]. In addition, it is pointed out in Ref. [2] that these counties have been regarded as separate cultural regions characterized by their own manners and customs different from each other. This tendency was already seen in the medieval times [2], and its influence might still have been continuing in the early Edo period, with that of the geometric arrangement of the counties. The above factors may have caused an increase in the psychological distance along the E-W direction in the northern part of Akita Domain, at least in the early Edo period.

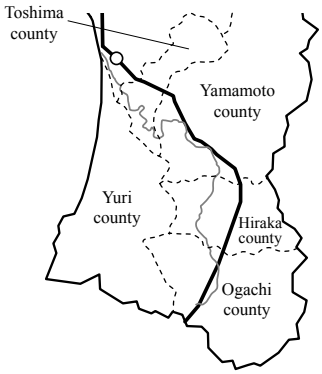
As for the southern part of Akita Domain, on the other hand, its situation in the Sengoku period was as follows. As shown in **Fig. 7**, the areas along *Ushū Kaidō* Road had been divided into four counties not in the E-W direction but in the N-S direction: Toshima, Yamamoto, Hiraka and Ogachi counties [11]. In addition, the Yuri county existed on the west of the above counties as shown in the figure [11]. The clans of the feudal lords of these counties frequently fought with each other through the Sengoku period [12]. Battles occurred not only against the Yuri counties, i.e., along the E-W direction, but also among the four roadside counties, i.e., along the N-S direction. Therefore, it is unlikely that the geometric arrangement of the above counties contributed to the E-W stretch of the map of *Ushū Kaidō* Road. To infer the cause of the above stretch, other factors should be considered for the southern part of Akita Domain.

It is well known that the living conditions of the coastal and inland regions in the southern part of Akita Domain are clearly distinct from each other with respect to the characteristics of geography and climate [3]. **Figure 8** shows the overview of the geographic and climate characteristics of the southern part of Akita Domain. As shown in the figure, the coastal region consists of two plains: Akita and Honjō Plains. On the other hand, Yokote Basin exists in the inland region as already mentioned in Section 2.1. The above two regions are geographically separated by Dewa Mountains ranging from south to north through the central area of Akita Domain. It has been pointed out that the mountains separating two regions make the people in these two regions difficult to interact with each other [11]. This suggests that the above geographic separation might have amplified the psychological distance between the coastal and inland



Sengoku feudal lord in each county
Kazuno: Narita clan, Akimoto clan, Nara clan and Anbo clan
Hinai: Asari clan
(Ani: Kannari clan)
Noshiro: Hiyama-Ando clan

Fig. 6 Division of the northern part of Akita Domain in the Sengoku period (i.e., late medieval times before the Edo period) [11].



Sengoku feudal lord in each county
Toshima: Toshima clan
Yamamoto: Tozawa clan, Hondō clan and Rokugō clan
Hiraka: Onodera clan
Ogachi: (not described in Ref. [11])
Yuri: Hanekawa clan, Akōzu clan, Nikaho clan and Ōishi clan

Fig. 7 Division of the southern part of Akita Domain in the Sengoku period (i.e., late medieval times before the Edo period) [11].

regions.

On the other hand, the climate of the coastal and inland regions in the southern part of Akita Domain is considerably different, especially in the wintertime [3], as described in Fig. 8. The average temperature in January and the average amount of the maximum snowfall are −0.6°C and 42 cm in the coastal region, whereas those are −2.0°C and 117 cm in the inland region [3]. This means that the inland region is much colder in the wintertime with a large amount of snowfall, compared with the coastal region. This climate difference might also have contributed to the amplification of the psychological distance between

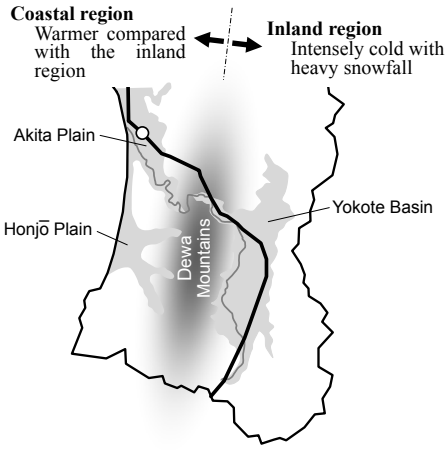


Fig. 8 Geographic and climate characteristics of the southern part of Akita Domain.

the two regions.

The above factors, i.e., the geometric arrangement of the Sengoku-period counties in the northern part and the geographic and climate conditions in the southern part, might have caused the E-W stretch in the map of Akita Domain created in the early Edo period. This indicates the possibility that the cause of the map distortion is different depending on the place.

On the other hand, a remarkable map-distortion characteristic is seen only in the map created in the earlier period when map creation technology was not as advanced as it was in the later periods. According to Ref. [13], in fact, the map revision work to correct the geometric errors in the Akita Domain maps started in the middle of the 18th century, i.e., in the mid Edo period. The map of (a) was created before this revision work, and the results of the work are thought to have been reflected in (b) and (c) in which the amount of distortion is reduced. Therefore, it is presumed that the cognitive structure constructed based on the psychological image was reflected only in the map created in the early Edo period, whereas mostly not reflected in those created in the mid and late Edo periods.

5. Conclusion

In this study, the distortion characteristics of the historical maps of *Ushū Kaidō* Road are quantitatively analyzed. The technique of the Euclidean regression analysis is used. The above approach made it possible to obtain a new insight into the cause of the distortion of the historical maps of *Ushū Kaidō* Road created in the Edo period. Specifically, the stretch of the map in the E-W direction is confirmed as a remarkable map-distortion characteristic seen in the early Edo period. It is presumed that the geometric arrangement of the counties in the Sengoku period

might have caused the stretch in the northern part, whereas the geographic separation by mountains and difference in climate conditions between the coastal and inland regions may be the cause in the southern part. The above map-distortion characteristic is mostly not seen in the maps created in the mid and late Edo period when the map creation technology was more advanced. Further verification of the obtained results will be the subject of future work.

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